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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Some fundamentally novel nonlinear optical devices were proposed and experimentally realized (in collaborative experiments with P.W. Smith, W.J. Tomlinson and J. Bjorkholm at Bell Laboratories). These results have been published in fourteen papers by the principal investigator (some of them in collaboration with researchers at Bell Laboratories, Holmdel, NJ, and Max-Planck-Institute fur Quantenoptick, Garching, Germany). The univied theory of plane-wave reflection and reflection at nonlinear interfaces was considered. Excitation of inhomogeneous traveling waves, which are peculiar features for "negative"

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nonlinearity, have been studied. It was shown analytically that in the case of limited (Gaussian) beam incidence, the nonlinear surface wave, observed in some recent computer simulations, is strictly forbidden, and an approximate theory of reflection in such a case has been developed.

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Final Scientific Report

Theoretical Study of Nonlinear Surface and Inhomogeneous Processes and Their Applications to Optical Bistability

Submitted to

U.S. Air Force Office of Scientific Research
Bolling Air Force Base, Washington, DC 20332
Attention: Dr. H. Schlossberg

by

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May 13, 1982

Theoretical Study of Nonlinear Surface and Inhomogeneous Processes and Their Applications to Optical Bistability

This research started on 1 April 1980 and finished on 15 March 1982; the total duration covered by this report on this research under AFOSR support is 20.5 months. Within this period, a number of new theoretical results were obtained. Based on these results, some fundamentally novel nonlinear optical devices were proposed and experimentally realized (in collaborative experiments with P.W. Smith, W.J. Tomlinson and J. Bjorkholm at Bell Laboratories). These results have been published in fourteen papers by the principal investigator (some of them in collaboration with researchers at Bell Laboratories, Holmdel, N.J. and Max-Planck-Institut fur Quantenoptick, Garching, Germany), see list attached.

The research progressed basically in five directions:

(i) Nonlinear interfaces and optical bistability.[2,3,10]

The unified theory of plane-wave reflection and reflection at nonlinear interfaces was considered in Ref. 2. Excitation of inhomogeneous traveling waves, which are peculiar features for "negative" nonlinearity, has been studied in Ref. 4. It was shown analytically[10] that in the case of limited (Gaussian) beam incidence, the nonlinear surface wave, observed in some recent computer simulations, is strictly forbidden, and an approximate theory of reflection in such a case has been developed.

(ii) It was proposed[1,3] to obtain optical bistability at the electro-optically driven interface, which serves as an "artificial" nonlinearity. Very recently, this kind of bistability was realized in a collaborative experiment;[13] very low operating power in the cw regime was achieved.

(iii) Fundamentally novel optical bistable effects were proposed and experimentally observed in collaborative work with researchers at Bell Labs.[5,7,9] and theoretically studied.[6,8] These effects allow one to obtain optical bistability based on mutual self-trapping of counterpropagating beams of light (or, in general, any kind of mutual self-action,[8] including self-focusing, self-defocusing, or self-bending) without employing a nonlinear Fabry-Perot interferometer. Both of the mentioned systems, nonlinear interfaces [see (i)] and self-action systems, form a new, <u>cavityless</u> class of optical bistable devices, which do not include any kind of optical resonators, and, therefore, allow one (a) to avoid resonant frequency tuning; (b) to use broadband light sources; and (c) to attain high operational speed.

(iv) Two novel effects related to optical bistability in ring resonators were proposed and theoretically studied in Refs. 11 and 12. Both of these effects are based on nonreciprocity, induced by strong counterpropagating waves in nonlinear ring resonator. Under certain conditions, this nonlinear non-reciprocity leads to the damping of one wave by the other; i.e. the wave propagating in one of the directions becomes dominant. This causes the appearance of directionally-asymmetrical bistability.[12] At the onset of such bistability, nonlinear non-reciprocity suggests considerable enhancement[11] of linear non-reciprocity, such as a Sagnac effect in the rotating ring resonator. The factor of this enhancement can be as large as 10^3-10^4 which could be extremely useful for developing sensitive gyro-laser systems.

(v) A novel effect of bistable interaction of EM wave with single electron was predicted.[14] It was shown theoretically that even a very weak relativistic change of mass of the electron can result in large nonlinear effects in forced cyclotron resonance. In particular, it gives rise to the hysteretic jumps of the kinetic energy of the electron, if the intensity or frequency of the forcing wave is varied. The proposed effect is important because it suggests for the first time a bistable interaction of the EM wave with the simplest microscopic physical object. This differs fundamentally from all known kinds of optical bistability which so far has been based on macroscopic properties of the media. An analogous effect may also be observed in semiconductors (such as InSb); it can be based[14] on the dependence of effective mass of the electron on energy of its excitation.

A.E. Kaplan
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